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MAGNETOELASTIC ELECTROMECHANICAL SYSTEMS FOR POWER HARVESTING FROM VIBRATION

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Abstract. The paper addresses the problem of vibration-to-electric energy conversion using magnetostrictive materials. Theoretical and experimental results of the study of the magnetostrictive electric transducers (MET) for power harvesting from vibration are presented. Both simulations and experimental data have confirmed functionality of the designed MET using giant magnetostrictive material TERFENOL-D.

Introduction. Magnetostriction is a transduction process where magnetic energy is converted to mechanical energy. It is called the *Joule effect*, and is the most common magnetostrictive mechanism employed in magnetostrictive actuators. Magnetostrictive materials exhibit a change in dimension when placed under a magnetic field. There exists also an inverse process in magnetostrictive samples where mechanical energy is converted to magnetic energy. That is, by applying a mechanical stress to a magnetostrictive material, the magnetization along the direction of the applied stress of the material varies due to the magnetostrictive effect. The flux variation obtained in the material can be used to induce an electromotive force in a coil surrounding the material. This process in magnetostrictive materials is called the *Villari effect* and is used in magnetostrictive sensors. In the last few years, there has been a surge of research in the area of power harvesting from vibration using smart materials for developing alternative power sources for different applications, see e.g. [1-3].

Modeling. Operation of power harvesting devices (PHD) and other transducers that use magnetostrictive materials is based on dynamic interaction between magnetic and electric fields, inherent elastic properties of active material and mechanical external loads. To use this interaction in an optimal way the proper mathematical models of controlled electro-magneto-elastic multibody systems need to be developed. In the paper general mathematical model of multibody system with magnetostrictive transducers is presented. The model consists of the constitutive equations of magnetoelastic behavior of transducers, standard formulae of electromagnetism for induced voltage and current in the pick-up coil due to variation of magnetic field intensity, and finally the equations of motion of multibody system itself. General model has been developed in details for linearized dynamics of magnetostrictive transducers and implemented virtually for two practically important cases of interaction of hosting multibody system with

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transducers, namely for system with displacement driven transducers and for system with force driven transducers.

Simulation and Model Validation. Simulations of operation of MET have been done using developed model. Physical prototype of MET and test rig have also been built and used successfully for experimental study of power harvesting from vibration and for validation of developed model. Analysis of simulations has shown that electrical power output of MET is sensitive with respect to electrical load, mechanical prestress, frequency and level of external periodic excitation. A comparison of the obtained experimental data and respective model output data for power output and for voltage shows that experimental and simulation data are in reasonable proximity [2].

Conclusion. Both simulation results and experimental data have confirmed validity of developed mathematical models and functionality of the designed MET using giant magnetostrictive material Terfenol-D. A video showing designed magnetostrictive power harvesting device in real-time operation can be found via the web link
http://www.am.chalmers.se/~berbyuk/chalmers_magnetostrictive_generator.MOV

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References

1. *Sodano H.A., Inman D.J. and G. Park,* A review of power harvesting from vibration using piezoelectric materials // *The Shock and Vibration Digest,* May 2004, **36,** No.3, pp. 197-205
2. *Berbyuk V.,* Towards dynamics of controlled multibody systems with magnetostrictive transducers // *J. of Multibody System Dynamics,* 2007, **Vol. 18**, pp. 203-216, http://dx.doi.org/10.1007/s11044-007-9078-y
3. *Berbyuk V., and J. Sodhani,* Towards modeling and design of magnetostrictive electric generators // *J. Computers and Structures,* 2008, **Vol. 86,** pp. 307-313, http://dx.doi.org/10.1016/j.compstruc.2007.01.030

МАГНЕТОПРУЖНІ ЕЛЕКТРОМЕХАНІЧНІ СИСТЕМИ ДЛЯ ПЕРЕТВОРЕННЯ МЕХАНІЧНОЇ ЕНЕРГІЇ ВІБРАЦІЙ В ЕЛЕКТРИЧНУ ЕНЕРГІЮ

Побудована математична модель та алгоритм розрахунку процесів перетворення механічної енергії вібрацій в електричну енергію в пристроях що моделюються магнетопружними електромеханічними системами. Достовірність моделі та запропонованої концепції перетворювачів підтверджено експериментальними дослідженнями створеного магнетоелектричного перетворювача на основі магнетостриктивного матеріалу TERFENOL-D.